DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF–916
HOWARD AND OTHERS - YOUNG FAULTS, U. S.
SHEET 2 OF 2

EXPLANATION

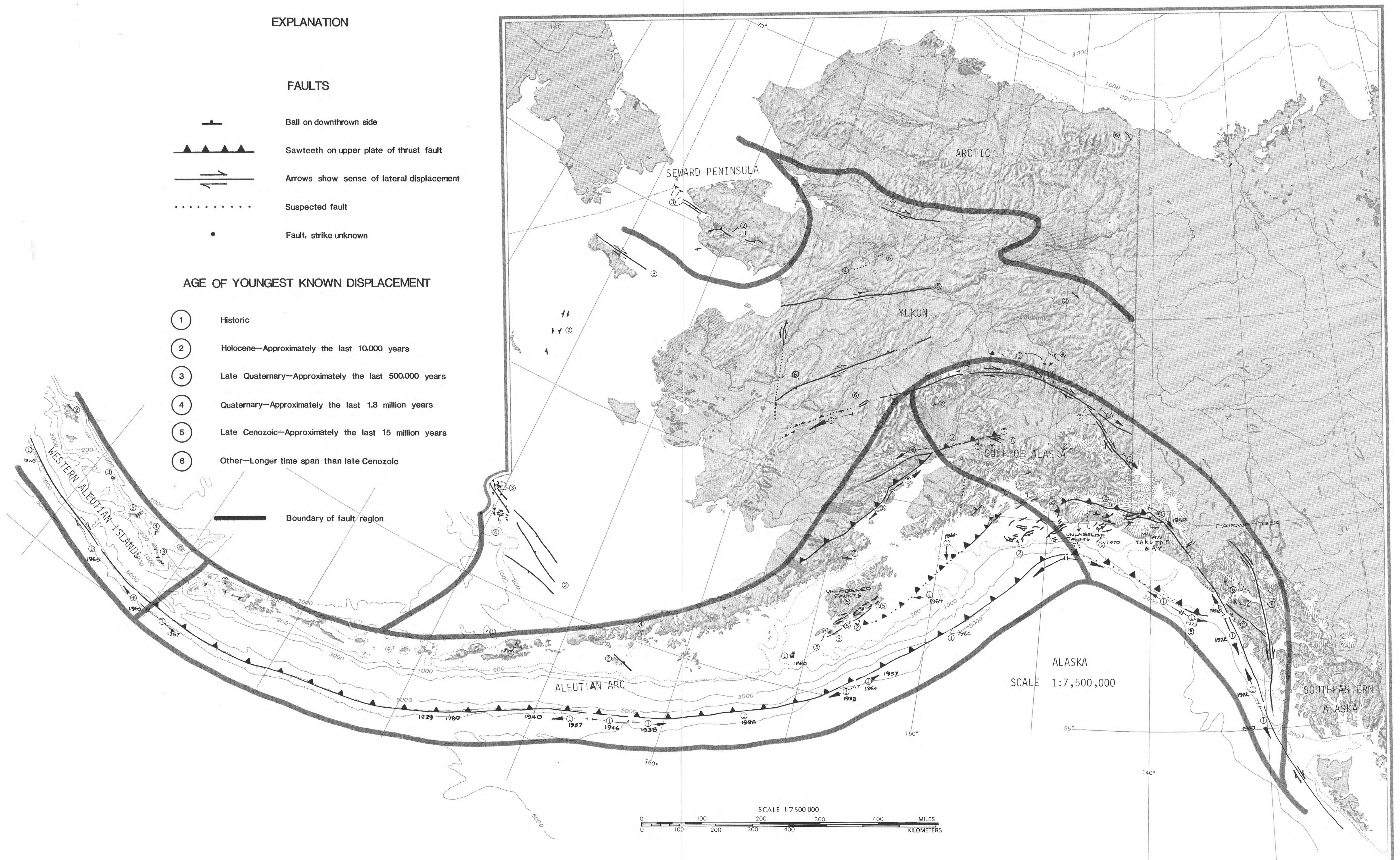
FAULTS

- Ball on downthrown side
- Sawteeth on upper plate of thrust fault
- Arrows show sense of lateral displacement
- Suspected fault
- Fault, strike unknown

AGE OF YOUNGEST KNOWN DISPLACEMENT

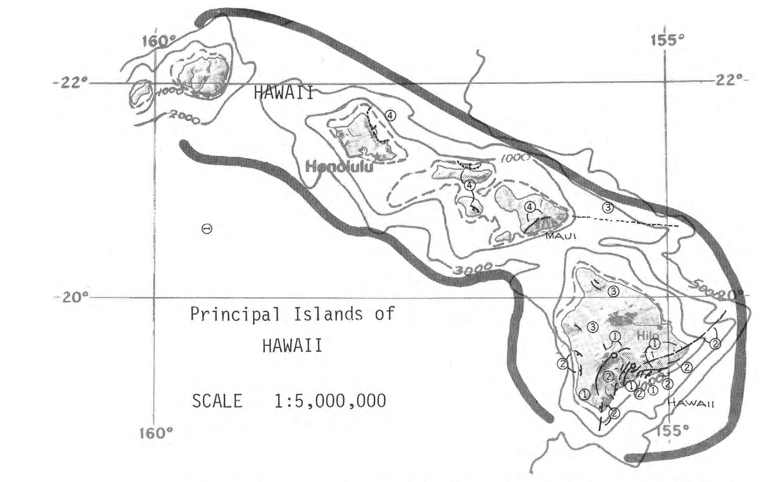
1. Historic
2. Holocene--Approximately the last 10,000 years
3. Late Quaternary--Approximately the last 500,000 years
4. Quaternary--Approximately the last 1.8 million years
5. Late Cenozoic--Approximately the last 15 million years
6. Other--Longer time span than late Cenozoic

Boundary of fault region

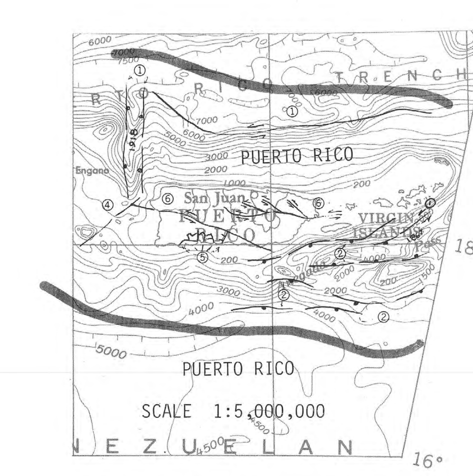


BATHYMETRIC CONTOURS IN METERS

BASE FROM U.S. GEOLOGICAL SURVEY, 1970
BATHYMETRIC CONTOURS FROM TECTONIC MAP OF NORTH AMERICA, 1969



BASE FROM U.S. GEOLOGICAL SURVEY, 1:7,500,000, 1970



BASE FROM U.S. GEOLOGICAL SURVEY TECTONIC MAP OF NORTH AMERICA, 1969

Scale 1:5,000,000

FIGURE 1. MAP SHOWING PROVINCES WHICH ARE SUBDIVIDED INTO REGIONS OF CHARACTERISTIC FAULTING

DATA GATHERED IN 1975

INTRODUCTION

Fault movement can pose a major hazard to man and his constructions. The recognition of active faults is important for engineering practice and land-use planning because surface faulting can displace engineering structures and because most episodes of abrupt fault movement are associated with earthquakes. This map gives an overview of geologically young faults and is intended to help in evaluation of the potential activity of faulting nationally. The map is a progress report. Because of its scale, it cannot be used as an index of specific faults or fault hazards. However, it offers a synopsis, as of 1975, of more extensive data that must be taken into consideration in assessments of hazards from faulting.

An active fault may be defined as a break in the earth's crust upon which movement has occurred in the recent geologic past and future movement is expectable. Recognizing active faults, however, is a difficult problem. The major criteria are historic records of movements, evidence for movement in the recent geologic past, or spatially related earthquakes (seismicity). Difficulties in recognizing active faults include: (1) the scantiness of geologic data on recency of movement, (2) low precision in locations of earthquakes, (3) incomplete geologic mapping so that many faults are still unrecognized, and (4) great uncertainty about the length of time that faults can lie dormant and still be capable of future movement. Furthermore, the risk to local engineering structures and population influences the criteria that are used to identify faults as active. Because of these difficulties, the criteria for designating faults as active or potentially active vary among earth scientists.

This map shows faults that geologists working in different regions believe to have had movement geologically recent enough to be of significance in the evaluation of future fault activity. Such selection involves subjective judgments. The map includes all faults known to us to have undergone movement in Quaternary time (last 1.8 million years). We assume that fault processes acting in this geologically short time interval can generally be expected to continue. In addition, many other faults are shown for which possible Quaternary movement is suspected but not proven. For some faults, movement has been historic, actually observed, or in a few cases inferred from geophysical data on earthquakes. For most faults, movement in the geologic past is indicated by offset of strata of known age. The geologic age of the youngest rocks known to be displaced is shown on the map by a number code (1 to 6) to indicate age of youngest known displacement. Larger numbers represent progressively longer time spans before the present and greater uncertainty in age of youngest movement. There may have been younger movement on some of the faults shown in the longer time-span categories, but no evidence is available to identify such movement. For instance, a category 5 fault may be suspected to have moved within the last million years but only proven to have moved within the last 15 million years.

The youth of faults selected to be included varies across the map, as shown by the following examples. No proof is known for fault movement as young as Quaternary in the Atlantic states, but damaging earthquakes have occurred. Faults that cut deposits even 60 million years old are anomalously young in this relatively stable terrane, and such faults, therefore, are included on the map if no evidence is available to disprove much younger movement. On the contrary, faults in California and Nevada are shown on the map generally only if Quaternary movement is proven. This is because evidence for young fault movement in the western states is much more abundant than in the east. Geologic data in Oregon and the northern Rocky Mountains are commonly insufficient to prove whether or not Quaternary movement has occurred; thus, included on the map are many faults for which the age of youngest proven movement is older than Quaternary, but for which younger movement may be suspected.

Some faulting is characterized by sudden movements and accompanied by earthquakes, whereas other faulting is characterized by slow creep and little or no seismicity. Earthquake magnitude is related to fault length, so long faults generally pose a greater hazard than short faults. Recorded earthquakes provide one clue to regional earthquake hazards. By using the age, length, and style of faulting to assess possibilities of future faulting and earthquake hazard, the short historic record of seismicity can be extended to cover a longer, geologic sample of time.

Faults can be classified according to their sense of offset, or displacement. Strike-slip faults have horizontal relative movement, left or right lateral according to the direction of displacement of the block across the fault from the observer. Dip-slip faults are of three kinds: (1) thrust faults in which one block of rock overrides another along a gently inclined fault surface, (2) reverse faults which are similar to thrust faults, but steeper and (3) normal faults which are inclined faults in which the upper block of rock moves down the inclined fault surface. Oblique-slip faults involve movement intermediate between strike-slip and dip-slip. Spreading or extension of the earth's crust is generally implied by normal faults, whereas compression or shortening is implied by thrust and reverse faults.

Regional patterns of faulting can be important for assessing possible activity. For example, relatively frequent continued faulting is likely in most areas of known historic or Holocene faulting. Regions in which geologically young faults have a characteristic style are outlined on the map and described below. Two examples will illustrate how the boundaries between regions were drawn: (1) Faults in the western Nevada region and the Nevada-Utah region are similar in many respects, but the youngest (late Quaternary) faults are long in western Nevada and short in the Nevada-Utah region. (2) In the eastern United States, a southeast region is outlined in which the youngest known faults are reverse faults in contrast to normal faults in adjacent regions. The boundaries between regions are gradational.

This map has been compiled using data generously provided by many earth scientists. Data availability across the country is very uneven. For example, great attention has long been paid to mapping young faults in some areas, such as California, although undoubtedly many young faults remain to be found there. Few modern searches for young faults have been made in other areas, notably the mid-continent, and much of the continental shelves offshore have not been searched. Some areas lack young datable strata.

The major areas of responsibility of the map compilers are as follows: K. A. Howard, map coordination, southwest states, Hawaii; J. M. Aaron, Puerto Rico; E. E. Brabb, California; M. R. Brock, central states; H. D. Gower, Oregon, Washington; S. J. Hunt, Alaska; D. J. Milton, continental shelves of conterminous U.S.; W. R. Muehlberger, Louisiana, Texas, Oklahoma, New Mexico; J. K. Nakata, map coordination; G. Plafker, Alaska; D. C. Prowell, eastern states; R. E. Wallace, Nevada, Utah; I. J. Witkind, Idaho, Montana, Wyoming, Colorado.

DESCRIPTIONS OF REGIONS

Regions of characteristic faulting are grouped according to the provinces indexed in figure 1.

HAWAII

Hawaii.--The Hawaiian Islands are volcanoes that are progressively younger toward the big island of Hawaii at the southeast end of the chain, which is active volcanically and seismically. The islands west of Maui are relatively stable and low in seismicity. Historic faulting in the two eastern islands (Maui and Hawaii) is of three types. In the first type, local faulting has accompanied the frequent historic eruptions on rift zones that radiate from Kilauea and Mauna Loa volcanoes on Hawaii Island; earthquakes suggest that similar eruption and fault activity occur on a similar rift off the east shore of Maui. A second major type of faulting, possibly gradational with the first, is faulting to seaward of giant landslide-like blocks; sudden displacements may be several meters and may be accompanied by tsunamis (seismic sea waves). A third, more local type of faulting accompanies periodic collapse of the summit craters (calderas) of Kilauea and Mauna Loa.

ARCTIC ALASKA

Arctic.--Little or no late Cenozoic tectonic activity is known in this region of low seismicity, which includes the Brooks Range and North Slope of Alaska.

CENTRAL ALASKA

Seward Peninsula.--This part of Alaska has minor seismicity and contains short Holocene and other Quaternary faults having mostly normal displacement.

Yukon.--This central part of Alaska contains many short faults with Holocene displacement, and several longer strike-slip faults, mostly along reactivated major breaks, having Quaternary and possible late Cenozoic displacement. Seismicity is moderate.

EASTERN GULF OF ALASKA

Gulf of Alaska.--The eastern Gulf of Alaska and adjacent mountains including the Alaska Range is a region of large faults with high tectonic and seismic activity. Strike-slip faulting predominates in the eastern part, and the style gradually changes to oblique and thrust faulting in the western part, where the sea floor is being thrust under the continent. A broad zone of shallow seismicity along the coast merges inland with a zone of shallow and intermediate seismicity; this implies that a major zone of thrust faulting underlies the entire inland part of the region, in addition to large strike-slip faults that break the surface there. Catastrophic strike-slip rupture of about 6 m occurred along the Fairweather fault in 1958. The Yakutat Bay area was affected by vertical tectonic displacement of as much as 14 m during a series of major earthquakes in 1899.

Southeastern Alaska.--Major submarine strike-slip faults closely associated with high seismicity exist along the continental margin. No geologically young faults are known from the interior of the region where current seismicity is low, but they could be present and unrecognized because of extensive water and vegetation cover.

ALEUTIAN

Aleutian Arc.--The eastern Aleutian arc and adjoining submarine slope north of the Aleutian submarine trench is one of the most seismically active regions in the world. It is underlain by a highly active northward-dipping zone of earthquakes that indicate major northward underthrusting of the Pacific sea floor. Major active thrust faults are thus believed to underlie the entire province and to surface in and near the trench at the south margin of the province. The map portrays this zone as a single fault along the trench. Dip-slip fault movement in excess of 20 m occurred during the 1964 earthquake, resulting in uplift or submergence of coastal areas many kilometers broad, and generation of a tsunami (seismic sea wave).

Western Aleutian Islands.--The region is bordered on the southwest by an active zone of faulting between two oceanic trenches known as a transform fault boundary. A few short normal faults with Quaternary movement are known on land, and faults are possibly numerous offshore. Movement on the major transform fault zone offshore varies from oblique to strike slip.

NORTHWEST COAST

Puget-Olympic.--The Olympic Peninsula and Puget Sound region of Washington contains local evidence of Quaternary, including Holocene, faulting. Faulting includes strike-slip and reverse movement.

Oregon-Washington Coast.--The shallow offshore area contains numerous Quaternary faults apparently related to shale diapirs and to "growth faulting" or giant slumping. The continental slope farther offshore is marked by numerous Quaternary faults and folds that are related to compression of the deep sea floor against the continent. Faults are probably largely thrusts and reverse faults. A zone of thrusting may dip eastward under the slope, but if so activity along it is low and no seismic Benioff zone is known.

PACIFIC INTERIOR

Pacific Interior.--This region of the Sierra Nevada and Great Valley of California and the Cascade Range and Columbia River Plateau of the Pacific Northwest has undergone relatively little faulting in late Cenozoic time, in comparison with adjacent regions. Earthquakes in the region suggest that some active faults may be present, but ground rupture known to be geologically young is uncommon. Local surface faulting occurred in the Sierra Nevada in 1975. Long northwest-trending fracture zones in California (Foothills fault zone) and Washington (Olympia-Wallowa lineament) are suspected to contain geologically young faults.

SAN ANDREAS

California Coast.--Strike-slip faults mostly parallel to the coast dominate this highly seismic region, which includes the Coast Ranges and adjacent continental shelf. Some normal and thrust faults also are present. Fault density is high and it is likely many recently active faults are not yet discovered. Faulting has occurred through Cenozoic time and has been frequent in historic time. Strike-slip of more than 6 m occurred along the San Andreas fault in the 1906 San Francisco earthquake.

Transverse Ranges-Tehachapi.--Moderate to high-angle thrust and strike-slip faults of Quaternary age are very numerous in this part of southern California; most of them trend east-west. The strike-slip San Andreas fault also crosses this region. Violent movement along faults not previously suspected to be active took place during the Kern County earthquake of 1952 and the San Fernando earthquake of 1971. Faults in this region have generally wide zones of deformation.

Southern California Borderland.--Faulting has occurred throughout the Cenozoic, and the fault density is high. Faults in this offshore region have been mapped in some detail with specific attention to the date of youngest detected displacement. The longer northwest-trending faults probably have right-lateral strike slip.

Salton Trough.--This region of southern California has abundant long historically active faults, including the southern part of the San Andreas. Most faults trend northwest and show right-lateral offset. Six meters of horizontal offset took place on the Imperial fault in 1940. No major late Cenozoic faults have been recognized in much of the Peninsular Ranges along the southwest border of the region.

Western Mojave.--Large strike-slip faults are numerous in the western Mojave Desert. Most trend northwest and have right-lateral displacement; east-west left-lateral faults bound the province on the north and south. Precise geodetic measurements show current movement along several of the northwest-trending right-lateral faults. In addition, some historic surface faulting has been accompanied by earthquakes. The recency of fault activity generally decreases eastward in the region.

GREAT BASIN

Walker Lane.--This border region between southwest Nevada and the eastern front of the Sierra Nevada contains abundant normal, oblique-slip, and strike-slip faults. Faulting has been active through late Cenozoic time. Late Quaternary, including Holocene and historic, movement on many of the faults and current seismicity indicate a highly active region. Arcuate faults occur around three young volcanic collapse depressions or calderas on which additional infrequent collapse and volcanism could produce sudden offsets of tens or hundreds of meters.

Western Nevada.--Faulting has been frequent through the late Cenozoic and into historic time, and the region is active seismically. Several late Quaternary (including Holocene and historic) faults are tens of kilometers long. Most faults are normal or oblique slip. Geologic data about which of the faults have moved in Quaternary time are better than for many regions.

Utah-Nevada.--Faulting has been frequent throughout the late Cenozoic. Faults are predominantly normal or oblique-slip, but a few examples are strike-slip. Holocene and other Quaternary faults are common and one historic break is known. Long Quaternary faults are widespread, but faults known to have moved in late Quaternary time are shorter.

Wasatch-Tetons.--The Wasatch mountain front in Utah and the adjoining area north to Yellowstone have been abundantly faulted through the late Cenozoic, including many Holocene breaks. Young faults and fault systems are numerous and long, which together with current seismicity indicate an active region.

NORTHERN BASIN AND RANGE

Eastern Oregon-western Idaho.--Late Cenozoic normal faults are common in eastern Oregon and western Idaho. The western Snake River Plain in the southeast part of the region is a graben (fault valley) bounded by late Cenozoic normal faults. Quaternary movement is known along some faults, but geologic data on the age of youngest movement is scarce.

Snake River Plain.--The eastern Snake River Plain in Idaho is a lava-filled trough formed by rifting or downwarping. Seismicity is low in the plain, but Holocene lava eruptions and associated ruptures have taken place along faults trending northwest. Seismicity is high and young faults are abundant in the Yellowstone area at the east end of the region, where many of the faults are associated with major volcanic eruptions and related caldera collapse.

Northern Rockies.--The northern Rocky Mountains have many normal faults and some possible strike-slip faults of late Cenozoic age. Most were active in Miocene time (22 to 5 million years ago). There is also evidence for Quaternary movement. Historic movement has occurred locally, and the area is active seismically.

RIO GRANDE BASIN AND RANGE

Rio Grande.--Abundant high-angle normal faulting in the late Cenozoic has formed the Rio Grande trough and adjacent basins and ranges. Evidence for movements in the Quaternary is common. The Rio Grande fault systems blend northward with similar basin-and-range faults that are somewhat masked by the surrounding topography of high Colorado Rocky Mountains.

Mexican Highland.--This region of southeastern Arizona and adjacent New Mexico contains several faults with Quaternary displacement. The ground surface in nearby Sonora, Mexico, was displaced 7 m during a large earthquake in 1887. Faults in the province are normal, oblique, and probably strike slip. Abundant cracks and small faults have formed in association with the withdrawal of ground water, and these cracks may be partly tectonic in origin. Precise measurements show contemporary tectonic deformation.

INTERIOR PLATFORMS

Sonoran.--This region of southwestern Arizona and the eastern Mojave Desert of California has few Quaternary faults and low seismicity. The area was block-faulted in Cenozoic time but for the last few million years has been relatively stable compared to surrounding regions. Geologic information is scanty, and additional young faults may be present.

Arizona Mountain Belt.--This transitional belt between the Colorado Plateau and basin-and-range terranes to the southwest was faulted extensively in the Cenozoic, but only a few faults show evidence of Quaternary displacement. The faults are normal, reverse, oblique, and probably strike slip.

Grand Canyon.--The Grand Canyon region of the southwestern Colorado Plateau contains several long steep faults on which normal or reverse movement has occurred repeatedly at infrequent intervals since Precambrian time, more than half a billion years ago. Cenozoic offsets are generally small, except along the northwest margin of the region.

Four Corners.--The Colorado Plateau, which constitutes much of this region, has been relatively stable since Precambrian time. Mountain ranges of the Colorado Rockies in the northeast part of the region were faulted and uplifted in Tertiary time. The only major known Quaternary faults are high-angle faults around the Uncompahgre uplift in west-central Colorado, where uplift may be continuing.

Paradox.--The Paradox region in the middle of the Colorado Plateau contains numerous normal faults whose Quaternary activity is a consequence of flowage and solution of shallow underlying salt. Landslide-like ruptures may continue to occur but are not the result of tectonic processes. The region has low seismicity.

Wyoming.--The Wyoming region, including the Wyoming basin and some of the Wyoming mountain ranges, contains scattered faults of diverse trend. The trends differ markedly from those in the adjacent regions on the west and southeast. The faults are generally high-angle normal faults. Quaternary movement is known on a few.

CENTRAL AND EASTERN UNITED STATES

Mid-continent.--Information on geologically young faulting in the mid-continent region is poor due to the scarcity of young deposits and of detailed geologic mapping. Cenozoic deposits are possibly offset by the Kentucky River fault zone at the east side of the region, and Quaternary faulting is known in eastern Colorado. No surface faulting has yet been associated with seismic areas that trend northeast from the central Mississippi Valley to the St. Lawrence River or with a seismic area that trends north through Nebraska.

Central Mississippi Valley.--The lowland region midway along the Mississippi Valley has been shaken by severe earthquakes and contains high-angle faults with small Cenozoic offset. Unconsolidated and loosely consolidated surface sediments in the area between Cairo and Memphis were severely disturbed during the New Madrid earthquakes of 1811-1813 and have a high potential for failure during future large earthquakes.

Circum-Gulf.--This region of the coastal plain, mainly inland from the Gulf of Mexico, contains many long faults subparallel to the coast, with movement either down to seaward or forming long grabens (fault valleys). Faulting is progressively younger toward the coast and was associated with deposition of successively Gulfward-building sedimentary deltas. In the Texas part of the circum-Gulf region these "growth faults" appear to be overlain by undistrubed lower Quaternary deposits and are not shown on the map. In Alabama and Florida, Miocene strata are offset but no minimum limit on the age of faulting is established.

Gulf Coast.--The Gulf coast of Texas and Louisiana and the adjacent continental shelf contain abundant normal faults that are subparallel to the coast and down to seaward. These are "growth faults" that were most active during deposition of the young sediments they cut. Many continue to be active as shown by onshore drainage anomalies, lineaments, and scarps. The faulting is facilitated by high fluid pressure and by flowage of underlying salt, resulting in huge landslidelike blocks sliding toward the Gulf. The most recent faulting ranges from middle Cenozoic to Holocene, and generally it is younger seaward. Movement is by aseismic creep and may be millimeters per year. Man's removal of fluids (oil, gas, water) has enhanced movement locally, especially in the Houston-Galveston area. Demonstrated Quaternary movement on the Baton Rouge fault zone in Louisiana suggests that fault zones seaward from it are also young. Offshore fault density is high; as many as 25 late Pleistocene and Holocene faults are present in a single traverse 70 km long off south Texas. In addition to the growth faults, less regular faulting occurs around salt domes in the east half of the province.

Straits of Florida.--The Straits are a half graben (fault valley) with the maximum depression near the Cuban shore. The Florida continental shelf contains a series of scarps that may be normal faults similar to those in the Circum-Gulf region. The youngest age of faulting has not been established but there is no known evidence for current activity.

Southeast.--Definite faulting in the late Cenozoic (the last 15 million years) is unknown for this region which includes the Atlantic Coastal Plain and Piedmont. However, scattered reverse faults have been active within the last 60 million years (Cenozoic time). The age of last displacement is generally not established, and it is unknown whether the faults may be related to earthquakes that occur in the region. Known vertical offsets of Cenozoic strata are less than 40 m, and the faults are subparallel to the structural grain of the basement. Small normal faults accompany the reverse faults. Offshore, young sediments are thick and provide a favorable environment for detection of youthful faulting. About a third of the coastline has been studied rather thoroughly through moderate- and high-resolution seismic-reflection profiling, but no young faults have been found.

Northeast.--The degree of young faulting in New England and adjacent areas is poorly known. Pleistocene glaciation destroyed most, if any, onshore evidence that could have documented movements during the Cenozoic. Some small-scale vertical faults may be the result of glacial rebound. Offsets in some glacial deposits are generally, though uncertainly, attributed to shoving and collapse of the former ice sheet. Local disturbances of young bedded sediments offshore may likewise be the result of glacial action. Current seismicity has been interpreted to suggest that the Ramapo fault near New York City and the Clarendon-Linden fault near Buffalo possibly are active, although the youngest faulted rocks preserved in their vicinities are hundreds of millions years old. Young normal faults on the Atlantic Continental Shelf off New Jersey show offsets as great as 90 m at 4-5 km depth and 1.5 m offset in upper Quaternary sediments within 7 m of the sea floor. Isolated faults offshore from Rhode Island and south of Cape Cod may have been active into the late Cenozoic. Historic earthquakes suggest movement along undetected faults, which may or may not intersect the ground surface.

PUERTO RICO

Puerto Rico.--The Puerto Rico region has large faults, earthquakes, and tsunamis (seismic sea waves). The structural block comprising Puerto Rico and the Virgin Islands is bounded by three seismically active zones associated with the junction of the Caribbean and Americas tectonic plates. The plate junction, the major seismic feature, is a strike-slip fault zone along the Puerto Rico Trench that dips southward under Puerto Rico. Motion along this zone is associated with frequent shallow earthquakes between the trench and Puerto Rico and small intermediate-depth earthquakes under the island. Mona Canyon off the northwest corner of Puerto Rico contains steep normal faults associated with large earthquakes and tsunamis. Southwest of the Virgin Islands, the Anegada (Virgin Islands) Trough separates the Puerto Rico-Virgin Islands platform from the lesser Antilles. Earthquakes along the trough suggest that faults in the sea floor are active. The trough appears to be a graben or grabens but there is also evidence of strike-slip motion.

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Interior--Geological Survey, Reston, Va.--1977

PRELIMINARY MAP OF YOUNG FAULTS IN THE UNITED STATES AS A GUIDE TO POSSIBLE FAULT ACTIVITY

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